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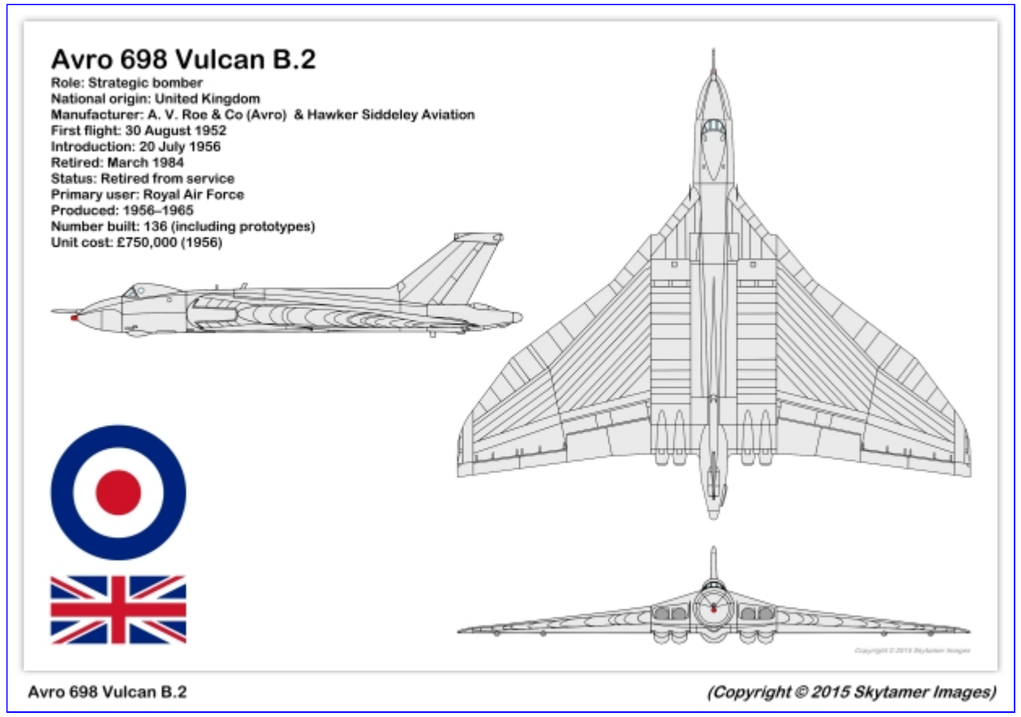
Avro 698 “Vulcan” B.2

United Kingdom — four-jet medium bomber



Avro 698 Vulcan B.2 (Copyright © 2015 Skytamer Images)

Archive Photos [1]

Avro 698 Vulcan B.2 (XH533), Airplane card: 1964 “History of Aviation, Second Series”, Bishops Stortford Dairy Products Ltd., Choicest Tips Tea, UK (The Skytamer Archive)

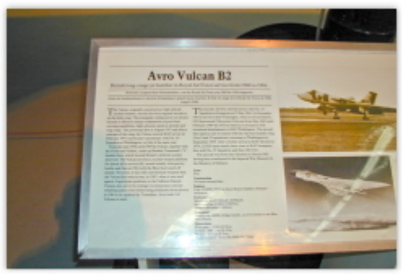
Avro Vulcan B.2 (XJ824) at the Imperial War Museum Duxford, Cambridgeshire, England c.1994

Avro 698 Vulcan B.2 (XJ824)

Avro 698 Vulcan B.2 (XJ824)

Avro 698 Vulcan B.2 (XJ824)

Avro Vulcan B.2 (XJ824) at the Imperial War Museum Duxford, Cambridgeshire, England (9 September 2002)]



Avro 698 Vulcan B.2 (XJ824)

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Avro 698 Vulcan B.2 (XJ824)

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Avro Vulcan B.2 (XL318) at the R.A.F. Museum Hendon, England (7 September 2002)

Avro 698 Vulcan B.2 (XL318)

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Avro Vulcan B.2 (XM598) at the R.A.F. Museum Cosford, England (12 September 2002)

Avro 698 Vulcan B.2 (XM598)

Avro 698 Vulcan B.2 (XM598)

Avro Vulcan B.2 (XM605) at the Castle Air Museum, Atwater, CA (24 February 2002)

Avro 698 Vulcan B.2 (XM605)

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Avro 698 Vulcan B.2 (XM605)

Avro Vulcan B.2 (XM605) at the Castle Air Museum, Atwater, CA (13 April 2007)


Avro 698 Vulcan B.2 (XM605)


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Avro 698 Vulcan B.2 (XM605)


Avro 698 Vulcan B.2 (XM605)

Overview [2]

- **Avro 698 Vulcan B.2**
- Role: Strategic bomber
- National origin: United Kingdom
- Manufacturer: A. V. Roe and Co Ltd. (Avro); Hawker Siddeley Aviation
- Designer: Roy Chadwick/Stuart Davies
- First flight: 30 August 1952
- Introduction: 20 July 1956
- Retired: March 1984
- Status: Retired from service
- Primary user: Royal Air Force
- Produced: 1956-1965
- Number built: 136 (including prototypes)
- Unit cost: £750,000 (1956)

The Avro Vulcan (sometimes referred to as the Hawker Siddeley Vulcan) is a jet-powered delta wing strategic bomber, which was operated by the Royal Air Force (RAF) from 1956 until 1984. Aircraft manufacturer A.V. Roe and Company (Avro) designed the Vulcan in response to Specification B.35/46. Of the three

V-bombers produced, the Vulcan was considered the riskiest option. Several scale aircraft, designated Avro 707, were produced to test and refine the delta wing design principles.

The Vulcan B.1 was first delivered to the RAF in 1956; deliveries of the improved Vulcan B.2 started in 1960. The B.2 featured more powerful engines, a larger wing, an improved electrical system and electronic countermeasures (ECM); many were modified to accept the Blue Steel missile. As a part of the V-force, the Vulcan was the backbone of the United Kingdom's airborne nuclear deterrent during much of the Cold War. Although the Vulcan was typically armed with nuclear weapons, it was capable of conventional bombing missions, a capability which was used in “Operation Black Buck” during the Falklands War between Britain and Argentina in 1982.

The Vulcan had no defensive weaponry, initially relying upon high-speed high-altitude flight to evade interception. Electronic countermeasures were employed by the B.1 (designated B.1A) and B.2 from circa 1960. A change to low-level tactics was made in the mid-1960s. In the mid-1970s nine Vulcans were adapted for maritime radar reconnaissance operations, redesignated as B.2 (MRR). In the final years of service six Vulcans were converted to the K.2 tanker configuration for aerial refueling. Since retirement by the RAF one example, B.2 (XH558), named “The Spirit of Great Britain” has been restored for use in display flights and air shows, whilst two other B.2s (XL426 and XM655) are kept in taxiable condition for ground runs and demonstrations at London Southend Airport and Wellesbourne Mountford Airfield respectively.

Development [2]

Origins

The origin of the Vulcan and the other V-bombers is linked with early British atomic weapon program and nuclear deterrent policies. Britain's atom bomb program began with Air Staff Operational Requirement OR.1001 issued in August 1946. This anticipated a government decision in January 1947 to authorize research and development work on atomic weapons, the U.S. Atomic Energy Act of 1946 (McMahon Act) having prohibited exporting atomic knowledge, even to countries that had collaborated on the “Manhattan Project”. OR.1001 envisaged a weapon not to exceed 24 ft 2 in (7.37 m) in length, 5 ft (1.5 m) in diameter and 10,000 lb (4,500 kg) in weight. The weapon had to be suitable for release from 20,000 ft (6,100 m) to 50,000 ft (15,000 m).

In January 1947, the Ministry of Supply distributed Specification B.35/46 to UK aviation companies to satisfy Air Staff Operational Requirement OR.229 for “a medium range bomber landplane capable of carrying one 10,000 lb (4,500 kg) bomb to a target 1,500 nautical miles (1,700 mi; 2,800 km) from a base which may be anywhere in the world.” A cruising speed of 500 knots (580 mph; 930 km/h) at heights between 35,000 ft (11,000 m) and 50,000 ft (15,000 m) was specified. The maximum weight when fully loaded ought not to exceed 100,000 lb (45,000 kg). In addition to a “Special” (i.e. atomic) bomb, the aircraft was to be capable of alternatively carrying a conventional bomb load of 20,000 lb (9,100 kg). The similar OR.230 required a “long range bomber” with a 2,000 nautical miles (2,300 mi; 3,700 km) radius of action with a maximum weight of 200,000 lb (91,000 kg) when fully loaded; this requirement was considered too difficult.

Required to tender by the end of April 1947, work began on receipt of Specification B.35/46 at Avro under the supervision of technical director Roy Chadwick and chief designer Stuart Davies. The type designation was Avro 698. It was very obvious to the design team that a conventional aircraft could not possibly satisfy the Specification. Knowing little about high-speed flight and unable to glean much from the Royal Aircraft Establishment or the US, the team investigated German swept wing research from the Second World War. The team estimated that an otherwise conventional aircraft, with a swept wing of 45°, would have doubled the weight requirement. Realizing that because swept wings increase longitudinal stability, the team deleted the tail (empennage) and the fuselage that supported it, the design becoming a swept-back flying wing with only a rudimentary forward fuselage and a fin (vertical stabilizer) at each wingtip. The estimated weight was now only 50% over the requirement. By reducing the wingspan and maintaining the wing area by filling in the space between the wingtips, the resulting delta shape enabled the designers to meet the Specification. Though Dr. Alexander Lippisch is generally credited as the pioneer of the delta wing, Chadwick's team had followed its own logical design process. The design as originally submitted had four large turbojets stacked in pairs buried in the wing either side of the centerline. Outboard of the engines were two bomb-bays. Five other companies submitted technical brochures to the same Specification.

In August 1947, Roy Chadwick was killed in the crash of the Avro Tudor 2 prototype and was succeeded by Sir William Farren. Reductions in wing thickness made it impossible to incorporate the split bomb bays and stacked engines, thus the engines were placed side-by-side in pairs either side of a single bomb-bay, the fuselage growing somewhat. The wingtip fins gave way to a single fin on the aircraft's centerline. Rival manufacturer Handley Page received a prototype contract for its crescent-winged HP.80 B.35/46 tender in November 1947. Though considered the best option, contract placement for Avro's design was delayed whilst its technical strength was established. Instructions to proceed with the construction of two Avro 698 prototypes was received in January 1948. As an insurance measure against both radical designs failing, Short Brothers received a contract for the prototype SA.4 to the less-stringent Specification B.14/46; the

SA.4, later named Sperrin, was not required. In April 1948, Vickers also received authority to proceed with their Type 660 which, although falling short of the B.35/46 Specification, being of a more conventional design would be available sooner - and entered service as Valiant.

Avro 707 and Avro 710

As Avro had no flight experience of the delta wing, the company planned two smaller experimental aircraft based on the 698, the one-third scale model 707 for low-speed handling and the one-half scale model 710 for high-speed handling. Two of each were ordered. However, the 710 was cancelled when it was considered too time-consuming to develop; a high-speed variant of the 707 was designed in its place, the 707A. The first 707 (VX784) flew in September 1949 but crashed later that month killing the pilot, Avro test pilot Flt Lt Eric Esler. The second low-speed 707 (VX790) built with the still uncompleted 707A's nose section (containing an ejection seat) and redesignated 707B, flew in September 1950 piloted by Avro test pilot Wg Cdr Roland “Roly” Falk. The high speed 707A (WD480) followed in July 1951.

Due to the delay of the 707 program, the contribution of the 707B and 707A towards the basic design of the 698 was not considered significant, though it did highlight a need to increase the length of the nosewheel to give a ground incidence of 3.5°, the optimum take-off attitude. The 707B and 707A proved the design's validity and gave confidence in the delta planform. A second 707A (WZ736) and a two-seat 707C (WZ744) were also constructed but they played no part in the 698's development.

Vulcan B.1 and B.2

Prototypes and Type Certification

More influential than the 707 in changing the design of the Avro 698 was the result of wind-tunnel testing by the Royal Aircraft Establishment at Farnborough. The outcome was that the wing needed redesign to avoid the onset of compressibility drag which would have restricted the maximum speed. Painted gloss white, the Avro 698 prototype (VX770) flew for the first time on 30 August 1952 piloted by Roly Falk flying solo. The prototype Avro 698, then fitted with only the first-pilot's ejection seat and a conventional control wheel, was powered by four Rolls-Royce RA.3 Avon engines of 6,500 lbf (29 kN) thrust. There were no fuel tanks fitted in the wing and temporary tankage was carried in the bomb bay. Avro 698 (VX770) made an appearance at the 1952 Society of British Aircraft Constructors' (SBAC) Farnborough Air Show the next month when Falk demonstrated an “almost vertical bank". After its appearance at Farnborough, there was much speculation as to what name the Avro 698 would be given by the RAF. Avro had strongly recommended the name Ottawa for the aircraft, in honor of the company's connection with Avro Canada. Weekly magazine Flight mused over the problem and after rejecting Avenger, Apollo and Assegai, suggested Albion. Nevertheless, the Chief of the Air Staff preferred a V-class of bombers and the Air Council announced the following month that the aircraft would be called the Vulcan after the Roman god of fire and destruction. The Handley Page HP.80 which first flew in December 1952 was called the Victor. In January 1953, Avro 698 (VX770) was grounded for the installation of wing fuel tanks, Armstrong Siddeley ASSa.6 Sapphire engines of 7,500 lbf (33 kN) thrust and other systems. The aircraft flew again in July 1953.

The second Avro 698 prototype (VX777) flew in September 1953. It was more representative of a production aircraft, it was lengthened to accommodate a longer nose undercarriage leg. It featured a visual bomb-aiming blister under the cabin and was fitted with Bristol Olympus 100 engines of 9,750 lbf (43.4 kN) thrust. The control wheel, at Falk's suggestion, was replaced by a fighter-style control stick. Both prototypes had almost pure delta wings with straight leading edges. During trials in July 1954, Avro 698 (VX777) received substantial damage during a heavy landing at Farnborough. It was repaired and fitted with Olympus 101 engines of 11,000 lbf (49 kN) thrust before resuming trials the following year. While exploring the high speed and high altitude flight envelope, mild buffeting and other undesirable flight characteristics were experienced while approaching the speed of sound, including an alarming tendency to enter an uncontrollable dive. The Aeroplane and Armament Experimental Establishment (A&AEE) at Boscombe Down found this unacceptable. The solution included the “Phase 2” wing, featuring a kinked and drooped leading edge and vortex generators on the upper surface, first tested on 707A (WD480). An auto-Mach trimmer introduced a nose-up attitude as the aircraft accelerated to a high Mach number; the control column had to be pushed rather than pulled to maintain level flight. Avro 698 (VX777) flew again in October 1955.

Meanwhile, the first production Avro 698 B.1 (XA889) had flown in February 1955 with the original wing. In September 1955, Falk, flying the second production B.1 (XA890) amazed crowds at the Farnborough Air Show by executing a barrel roll on his second flypast in front of the SBAC president's tent. After two days flying, he was called in front of service and civil aviation authorities and ordered to refrain from carrying out this “dangerous” maneuver. Now fitted with a Phase 2 wing Avro 698 B.1 (XA889) was delivered in March 1956 to the A&AEE for trials for the type's initial Certificate of Airworthiness which it received the following month.

Further Developments

The first 15 Avro 698 Vulcan B.1s were powered by the Olympus 101 of 11,000 lbf (49 kN) thrust. Many of these early examples in a metallic finish remained the property of the Ministry of Supply being retained for trials and development purposes. Those entering RAF service were delivered to No.230 Operational Conversion Unit (OCU), the first in July 1956. Later aircraft, painted in anti-flash white and powered by the Olympus 102 of 12,000 lbf (53 kN) thrust, began to enter squadron service in July 1957. The Olympus 102s were quickly modified to Olympus 104 standard, ultimately rated at 13,500 lbf (60 kN) thrust. As far back as 1952, Bristol Aero Engines had begun development of the BOl.6 (Olympus 6) rated at 16,000 lbf (71 kN) thrust but if fitted to the Avro 698 Vulcan B.1, this would have re-introduced the buffet requiring further redesign of the wing.

The decision to proceed with the Avro 698 Vulcan B.2 versions was made in May 1956. It was anticipated that the first Avro 698 Vulcan B.2 would be around the 45th aircraft of the 99 then on order. As well as being able to achieve greater heights over targets, it was believed that operational flexibility could be extended by the provision of in-flight refueling equipment and tanker aircraft. The increasing sophistication of Soviet air defenses required the fitting of electronic countermeasure (ECM) equipment and vulnerability could be reduced by the introduction of the Avro “Blue Steel” stand-off missile, then in development. In order to develop these proposals, the second Vulcan prototype (VX777) was rebuilt with the larger and thinner Phase 2C wing, improved flying control surfaces and Olympus 102 engines, first flying in this configuration in August 1957. Plans were in hand to equip all Vulcans from the 16th aircraft onwards with in-flight refueling receiving equipment. An Avro 698 Vulcan B.1 (XA903) was allocated for “Blue Steel” development work. Other Avro 698 Vulcan B.1s were used for the development of the BOl.6 (later Olympus 200), XA891; a new AC electrical system, XA893; and ECM including jammers within a bulged tail-cone and a tail-warning radar, XA895.

The 46th production aircraft and first Avro 698 Vulcan B.2 (XH533) first flew in September 1958 fitted with Olympus 200 engines of 16,000 lbf (71 kN) thrust, six months before the last Avro 698 Vulcan B.1 (XH532) was delivered in March 1959. Rebuilding Avro 698 Vulcan B.1s as Avro 698 Vulcan B.2s was considered but rejected over cost. Nevertheless, to extend the Avro 698 Vulcan B.1's service life, 28 were upgraded by Armstrong Whitworth between 1959 and 1963 to the Avro 698 Vulcan B.1A standard, including features of the Avro 698 Vulcan B.2 such as ECM equipment, in-flight refueling receiving equipment, and UHF radio. The second Avro 698 Vulcan B.2 (XH534) flew in January 1959. Powered by production Olympus 201 of 17,000 lbf (76 kN) thrust, it was more representative of a production aircraft, being fitted with an in-flight refueling probe and a bulged ECM tail cone. Some subsequent Avro 698 Vulcan B.2s were initially lacking probes and ECM tail cones, but these were fitted retrospectively. The first 10 Avro 698 Vulcan B.2s outwardly showed their Avro 698 Vulcan B.1 ancestry, retaining narrow engine air intakes. Anticipating even more powerful engines, the air intakes were deepened on the 11th Avro 698 Vulcan (XH557) and subsequent aircraft. Many of the early aircraft were retained for trials and it was the 12th Avro 698 Vulcan B.2 (XH558) that was the first to be delivered to the RAF in July 1960.

The 26th Avro 698 Vulcan B.2 (XL317) the first of a production batch ordered in February 1956, was the first Vulcan, apart from development aircraft, capable of carrying the “Blue Steel” missile; 33 aircraft were delivered to the RAF with these modifications. When the Mk.2 version of “Blue Steel” was cancelled in favor of the Douglas GAM-87 Skybolt air-launched ballistic missile in December 1959, fittings were changed in anticipation of the new missile, one under each wing. Though Skybolt was cancelled in November 1962, many aircraft were delivered or retrofitted with “Skybolt” blisters. Later aircraft (XL391 and XM574 onwards) were delivered with Olympus 301 engines of 20,000 lbf (89 kN) thrust. Two earlier aircraft were re-engined (XH557 and XJ784) for trials and development work; another seven aircraft (XL384-XL390) were converted circa 1963.

The last B.2 was delivered in 1965 and the type served till 1984. Whilst in service the B.2 was continuously updated with modifications including rapid engine starting, bomb-bay fuel tanks, wing strengthening to give the fatigue life to enable the aircraft to fly at low level (a tactic introduced in the mid-60s), upgraded navigation equipment, Terrain Following Radar (TFR), standardization on a common nuclear weapon (WE.117) and improved ECM equipment. The B.1As were not strengthened, thus all were withdrawn by 1968. Nine B.2s were modified for the Maritime Radar Reconnaissance (MRR) role and six for the airborne tanker role.

Proposals and Cancelled Projects

Avro had began work on developing successors to the Vulcan; such as the Avro 721, a smaller and more advanced bomber specifically for low level flying, building on Avro's extensive experience with delta wings. The Avro 730, a Mach 2.5 supersonic high altitude reconnaissance/bomber aircraft was a major project that may have replaced the V-bombers, but met with cancellation in 1957.

A airliner derivative of the Vulcan, to be known as the Avro Atlantic, was proposed and discussions were held with BOAC and Armstrong-Siddeley in the early 1950s about payload requirements. It would have retained the delta wings and buried engines of the Vulcan, and was projected to accommodate between 80 to

130 passengers; the Atlantic was to be capable of flying the London-New York route in five and a half hours.

Other countries expressed interest, but like the rest of the V-bombers, no foreign buyers for the Vulcans emerged. As early as 1954, Australia recognized that the English Electric Canberra was becoming outdated and evaluated aircraft such as the Avro Vulcan and Handley-Page Victor as potential replacements. Political pressure for a Canberra replacement only rose to a head in 1962; at which point more modern types such as the BAC TSR-2, General Dynamics F-111C, and North American A-5 Vigilante had become available. The RAF would have transferred several V-bombers, including Vulcans, to the RAAF if they had purchased the TSR-2, but the RAAF selected the F-111C.

Vulcan B.3

In 1960, the Air Staff approached Avro with a request into a study for a Patrol Missile Carrier armed with up to six Skybolt missiles capable of a mission length of 12 hours. Avro's submission in May 1960 was the Phase 6 Vulcan, which if built would have been the Vulcan B.3. The aircraft was fitted with an enlarged wing of 121 ft (37 m) span with increased fuel capacity; additional fuel tanks in a dorsal spine; a new main undercarriage to carry an all-up-weight of 339,000 lb (154,000 kg); and reheated Olympus 301s of 30,000 lbf (130 kN) thrust. An amended proposal of October 1960 inserted a 10 ft 9 in (3.28 m) plug into the forward fuselage with capacity for six crew members including a relief pilot, all facing forwards on ejection seats, and aft-fan versions of the Olympus 301.

Design [2]

Overview

In spite of its radical and unusual shape, the airframe was built along traditional lines. Except for the most highly stressed parts, the whole structure was manufactured from standard grades of light alloy. The airframe was broken down into a number of major assemblies: the center section, a rectangular box containing the bomb-bay and engine bays bounded by the front and rear spars and the wing transport joints; the intakes and center fuselage; the front fuselage, incorporating the pressure cabin; the nose; the outer wings; the leading edges; the wing trailing edge and tail end of the fuselage; the wings were not sealed and used directly as fuel tankage, but carried bladders for fuel in the void spaces of the wings; and there was a single swept tail fin with a single rudder on the trailing edge.

The normal crew of five, the first pilot, co-pilot, navigator radar, navigator plotter and air electronics officer (AEO) was accommodated within the pressure cabin on two levels, the pilots sitting on Martin-Baker 3K (3KS on the B.2) ejection seats whilst on the lower level, the rest of the crew sat facing rearwards and had to abandon the aircraft through the entrance door. The original B35/46 specification had specified a jettisonable crew compartment but this requirement was removed in a subsequent amendment and the issue of not providing the rear crew with ejection seats remained highly controversial, especially when a practical scheme to fit them was rejected. A rudimentary sixth seat was provided forward of the navigator radar for an additional crew member; the B.2 also had an additional seventh seat on the opposite side from the sixth seat and forward of the AEO. These seats were no more than cushions and a full harness and an oxygen and intercom facility. The visual bomb-aimer's compartment could be fitted with a T4 (Blue Devil) bombsight but in most B.2s, the space was eventually fitted with a vertically mounted Vinten F95 Mk.10 camera for the assessment of simulated low-level bombing runs.

Fuel was carried in 14 bag tanks, four in the center fuselage above and to the rear of the nosewheel bay and five in each outer wing. The tanks were split into four groups of almost equal capacity, each normally feeding its respective engine though cross-feeding was possible. The center of gravity was automatically maintained by electric timers which sequenced the booster pumps on the tanks. B.2 aircraft could be fitted with one or two additional fuel tanks in the bomb-bay.

Despite being designed before a low radar cross-section (RCS) and other stealth factors were ever a consideration, a Royal Aircraft Establishment technical note of 1957 stated that of all the aircraft so far studied, the Vulcan due to its shape appeared by far the simplest radar echoing object: only one or two components contributing significantly to the echo at any aspect, compared with three or more on most other types.

Avionics

The original Vulcan B.1 radio fit was: two 10-channel VHF transmitter/receivers (TR-1985/TR-1986) and a 24-channel HF transmitter/receiver (STR-18). The Vulcan B.1A also featured an UHF transmitter/receiver (ARC-52). The initial B.2 radio fit was similar to the B.1A though it was ultimately fitted with the ARC-52, a V/UHF transmitter/receiver (PTR-175), and a SSB HF transmitter/receiver (Collins 618T).

The Navigation and Bombing System (NBS) comprised an H2S Mk9 radar and a Navigation Bombing Computer (NBC) Mk.1. Other B.1 navigation aids included a Marconi radio compass (ADF), GEE Mk.3, Green Satin Doppler radar to determine the ground speed and drift angle, radio and radar altimeters, and ILS. TACAN replaced GEE in the B.1A and B.2 and Decca Doppler 72 replaced Green Satin in the B.2. A continuous display of the aircraft's position was maintained by a Ground Position Indicator (GPI).

Vulcan B.2s were eventually fitted with the twin-gyro free-running gyroscopic Heading Reference System (HRS) Mk.2, based upon the inertial platform of the “Blue Steel” missile, which had been integrated into the system when the missile had been carried. With the HRS a Navigator's Heading Unit (NHU) was provided which enabled the Navigator Plotter to adjust the aircraft heading, through the autopilot, by as little as 0.1 degrees. The B.2 (MRR) was additionally fitted with the LORAN C navigation system.

The original ECM fit as fitted to the B.1A and B.2 was: one Green Palm voice communications' jammer; two Blue Diver metric jammers; three Red Shrimp S-band jammers; a Blue Saga Passive Warning Receiver with 4 aerials (PWR); one Red Steer tail-warning radar; and window (chaff) dispensers. The bulk of the equipment was carried in a large extended tail cone, and a flat ECM aerial counterpoise plate mounted between the starboard tailpipes. Later equipment on the B.2 included: an L-band jammer (replacing a Red Shrimp); the ARI 18146 X-band jammer; replacing the Green Palm; the improved Red Steer Mk.2; infra-red decoys (flares); and the ARI 18228 PWR with its aerials that gave a squared top to the fin.

Color Schemes

The two prototype Vulcans were finished in gloss white. Early Vulcan B.1s left the factory in a natural metal finish; the front half of the nose radome was painted black, the rear half painted silver. Front-line Vulcan B.1s had a finish of anti-flash white and RAF “type D ” roundels. Front-line Vulcan B.1As and B.2s were similar but with ‘type D pale’ roundels.

With the adoption of low-level attack profiles in the mid-1960s, B.1As and B.2s were given a glossy Sea Grey Medium and Dark Green disruptive pattern camouflage on the upper surfaces, white under-surfaces and “type D” roundels. (The last 13 Vulcan B.2s, XM645 onwards, were delivered thus from the factory). In the mid-1970s: Vulcan B.2s received a similar scheme with matte camouflage, Light Aircraft Grey undersides, and “low-visibility” roundels; B.2(MRR)s received a similar scheme in gloss; and the front half of the radomes were no longer painted black. Beginning in 1979, 10 Vulcans received a wrap-around camouflage of Dark Sea Grey and Dark Green because, during Red Flag exercises in the USA, defending SAM forces had found that the grey-painted undersides of the Vulcan became much more visible against the ground at high angles of bank.

Controls

The aircraft was controlled by a fighter-type control stick and rudder bar which operated the powered flying controls (PFCs). Each PFC had a single electro-hydraulic powered flying control unit (PFCU) except the rudder which had two, one running as a back-up. Artificial feel and auto-stabilization in the form of pitch and yaw dampers were provided, as well as an auto Mach trimmer.

The flight instruments in the B.1 were traditional and included G4B compasses; Mk.4 artificial horizons; and zero reader flight display instruments. The B.1 had a Smiths Mk.10 autopilot. In the B.2, these features were incorporated into the Smiths Military Flight System (MFS), the pilots' components being: two beam compasses; two director-horizons; and a Mk.10A or Mk.10B autopilot. From 1966, B.2s were fitted with the ARI 5959 Terrain-following radar (TFR), built by General Dynamics, its commands being fed into the director-horizons.

The B.1 had four elevators (inboard) and four ailerons (outboard). In the B.2, these were replaced by eight elevons. The Vulcan was also fitted with six electrically-operated three-position (in, medium drag, high drag) airbrakes, four in the upper center section and two in the lower. There were originally four lower airbrakes but the outboard two were deleted before the aircraft entered service. A brake parachute was installed inside the tail cone.

Electrical and Hydraulic Systems

The main electrical system on the B.1/B.1A was 112V DC supplied by four 22.5 kW engine-driven generators. Backup power was provided by four 24V 40 Ah batteries connected in series providing 96V. Secondary electrical systems were 28V DC, single-phase 115V AC at 1600 Hz, and three-phase 115V AC at 400 Hz, driven by transformers and inverters from the main system. The 28V DC system was backed up by a single 24V battery.

For greater efficiency and higher reliability, the main system on the B.2 was changed to three-phase 200V AC at 400 Hz supplied by four 40 kVA engine-driven constant speed alternators. Standby supplies in the event of a main AC failure were provided by a Ram Air Turbine (RAT) driving a 17 kVA alternator that could operate at high altitude down to 20,000 ft (6,100 m), and an Airborne Auxiliary Power Plant (AAPP), a Rover gas turbine driving a 40 kVA alternator, which could be started once the aircraft was below an altitude of 30,000 ft (9,100 m). Secondary electrical supplies were similar to the B.1.

The change to an AC system was a significant improvement. The Vulcan's powered flying controls were hydraulically actuated but each Powered Flying Control Unit (PFCU) had a hydraulic pump which was driven by an electrical motor. Because there was no manual reversion, a total electrical failure would result in a loss of control. The standby batteries on the B.1 were designed to give enough power for 20 minutes of flying time but this proved to be optimistic and two aircraft, XA891 and XA908, crashed as a result.

The main hydraulic system provided pressure for: undercarriage raising and lowering and bogie trim; nosewheel centering and steering; wheelbrakes (fitted with Maxarets); bomb doors opening and closing; and (B.2 only) AAPP air scoop lowering. Hydraulic pressure was provided by three hydraulic pumps fitted to Nos. 1, 2 and 3 engines. An electrically operated hydraulic power pack (EHPP) could be used to operate the bomb doors and recharge the brake accumulators. A compressed air (later nitrogen) system was provided for emergency undercarriage lowering.

Engine

The Rolls-Royce Olympus, originally known as the “Bristol BE.10 Olympus ”, is a two-spool axial-flow turbojet that powered the Vulcan. Each Vulcan had four engines buried in the wings, positioned in pairs close to the center of the fuselage. Engine design began in 1947, intended to power the Bristol Aeroplane Company's own rival design to the Vulcan. The engine would later be developed into a reheated (afterburning) powerplant for the cancelled supersonic BAC TSR-2 strike bomber and the supersonic passenger transport Concorde.

As the prototype Vulcan VX770 was ready for flight prior to the Olympus being available, it first flew using Rolls-Royce Avon RA.3 engines of 6,500 lbf (29 kN) thrust. These were quickly replaced by Armstrong Siddeley Sapphire ASSa.6 engines of 7,500 lbf (33 kN) thrust. VX770 later became a flying test bed for the Rolls-Royce Conway. The second prototype VX777 first flew with Olympus 100s of 10,000 lbf (44 kN) thrust. It was subsequently re-engined with Olympus 101 engines of 11,000 lbf (49 kN) thrust. When VX777 flew with a Phase 2C (B.2) wing in 1957, it was fitted with Olympus 102 engines of 12,000 lbf (53 kN) thrust.

Early B.1s were engined with the Olympus 101. Later aircraft were delivered with Olympus 102s. All Olympus 102s became the Olympus 104 of 13,000 lbf (58 kN) thrust on overhaul and ultimately 13,500 lbf (60 kN) thrust on uprating. The first B.2 flew with the second-generation Olympus 200 of 16,000 lbf (71 kN) thrust, design of which began in 1952. Subsequent B.2s were engined with either the uprated Olympus 201 of 17,000 lbf (76 kN) thrust or the Olympus 301 of 20,000 lbf (89 kN) thrust. The Olympus 201 was designated 202 on being fitted with a rapid air starter.

Operational History [2]

Introduction

In September 1956, the RAF received its first Vulcan B.1 (XA897) which immediately embarked upon a round-the-world tour. The tour was to be an important demonstration of the range and capabilities of the aircraft, it also had other benefits in the form of conducting goodwill visits in various countries; in later life Vulcans routinely visited various nations and distant parts of the former British Empire as a show of support and military protection. This first tour, however, was struck by misfortune; on 1 October 1956, while landing in bad weather at London Heathrow Airport at the completion of the world tour, XA897 was destroyed in a fatal accident.

The first two aircraft were delivered to 230 OCU in January 1957 and the training of crews started on 21 February 1957, in the following months more aircraft were delivered to the OCU. The first OCU course to qualify was No.1 Course, on 21 May 1957, and they went on to form the first flight of No.83 Squadron. No.83 Squadron was the first operational squadron to use the bomber, at first using borrowed Vulcans from the OCU and on 11 July 1956 it received the first aircraft of its own. By September 1957, several Vulcans had been handed over to No.83 Squadron The second OCU course also formed a Flight of No.83 Squadron, but subsequent trained crews were also used to form the second bomber squadron, No.101 Squadron. The last aircraft from the first batch of 25 aircraft had been delivered by the end of 1957 to No.101 Squadron.

In order to increase the mission range and flight time for Vulcan operations, in-flight refueling capabilities were added in 1959 onwards; several Valiant bombers were refurbished as tankers to refuel the Vulcans. Continuous airborne patrols proved untenable, however, and the refueling mechanisms across the Vulcan fleet fell into disuse in the 1960s. Both Vulcans and the other V-force aircraft routinely visited the Far East, in particular Singapore, where a fully equipped nuclear weapons storage facility had been constructed in 1959. During the Indonesia-Malaysia confrontation Britain planned to deploy three squadrons of V-bomber aircraft and 48 Red Beard tactical nuclear weapons to the region, although this was ultimately decided against, Vulcans trained in the region for both convention and nuclear missions. Britain regularly deployed of Vulcans to the Far East as a part of their contribution to SEATO operations, often to test the defenses of friendly nations in joint exercises. In the early 1970s, the RAF decided to permanently deploy two squadrons of Vulcans overseas in the Near East Air Force Bomber Wing, based at RAF Akrotiri in Cyprus; the Vulcans were withdrawn as Cypriot inter-communal violence intensified in the mid-1970s.

Vulcans did some very long range missions. In June 1961, one of them took off from RAF Scampton to Sydney, with a 18,507 km long journey, flown in only a bit more than 20 hours and three air refuelings. Vulcans frequently visited the United States during the 1960s and 1970s to participate in air shows and static displays, as well as to participate in the Strategic Air CommanD's Annual Bombing and Navigation Competition at such locations as Barksdale AFB, Louisiana and the former McCoy AFB, Florida, with the RAF crews representing Bomber Command and later Strike Command. Vulcans also took part in the 1960, 1961, and 1962 “Operation Skyshield” exercises, in which NORAD defenses were tested against possible Soviet air attack, the Vulcans simulating Soviet fighter/bomber attacks against New York, Chicago and Washington. The results of the tests were classified until 1997. Another successful use of the Vulcan happened with the 'Giant Voice' exercise, 1974. Even then, when Vulcan was quite obsolescent, RAF bombers managed to avoid USAF interceptors.

Nuclear Deterrent

As part of Britain's independent nuclear deterrent, the Vulcan initially carried Britain's first nuclear weapon, the “Blue Danube” gravity bomb. “Blue Danube” was a low-kiloton yield fission bomb designed before the United States detonated the first hydrogen bomb. These were supplemented by U.S. owned Mk.5 bombs (made available under the Project E program) and later by the British “Red Beard” tactical nuclear weapon. The UK had previously embarked on its own hydrogen bomb program, and to bridge the gap until these were ready the V-bombers were equipped with an Interim Megaton Weapon based on the “Blue Danube” casing containing “Green Grass”, a large pure-fission warhead of 400 kt (1.7 PJ) yield. This bomb was known as “Violet Club”. Only five were deployed before the “Green Grass” warhead was incorporated into a developed weapon as “Yellow Sun Mk.1”.

The later “Yellow Sun Mk.2”, was fitted with “Red Snow”, a British-built variant of the U.S. W28 warhead. “Yellow Sun Mk.2” was the first British thermonuclear weapon to be deployed, and was carried on both the Vulcan and Handley Page Victor. The Valiant retained U.S. nuclear weapons assigned to SACEUR under the dual-key arrangements. “Red Beard” was pre-positioned in Singapore for use by Vulcan and Victor bombers. From 1962, three squadrons of Vulcan B.2s and two squadrons of Victor B.2s were armed with the “Blue Steel” missile, a rocket-powered stand-off bomb, which was also armed with the 1.1 Mt (4.6 PJ) yield “Red Snow” warhead.

Operationally, RAF Bomber Command and the U.S. Strategic Air Command cooperated in the “Single Integrated Operational Plan” (SIOP) to ensure coverage of all major Soviet targets from 1958, 108 aircraft of the RAF's V-Bombers were assigned targets under SIOP by the end of 1959. From 1962 onwards, two jets in every major RAF base were armed with nuclear weapons and on standby permanently under the principle of Quick Reaction Alert (QRA). Vulcans on QRA standby were to be airborne within four minutes of receiving an alert, as this was identified as the amount of time between warning of a USSR nuclear strike being launched and it arriving in Britain. The closest the Vulcan came to take part in potential nuclear conflict was during the Cuban missile crisis in October 1962, where Bomber Command was moved to Alert Condition 3, an increased state of preparedness from normal operations, however stood down in early November.

The Vulcans were intended to be equipped with the American “Skybolt” Air Launched Ballistic Missile to replace the “Blue Steel”, with Vulcan B.2s carrying two “Skybolts” under the wings; the last 28 B.2s were modified on the production line to fit pylons to carry the “Skybolt”. Proposed in 1960 was a B.3 variant of the Vulcan, with increased wingspan to carry up to six “Skybolts”. When the “Skybolt” missile system was cancelled by U.S. President John F. Kennedy on the recommendation of his Secretary of Defense, Robert McNamara in 1962, “Blue Steel” was retained. To supplement it until the Royal Navy took on the deterrent role with Polaris submarines, the Vulcan bombers adopted a new mission profile of flying high during clear transit, dropping down low to avoid enemy defenses on approach, and deploying a parachute-retarded bomb, the WE.177B.

After the British Polaris submarines became operational and “Blue Steel” was taken out of service in 1970, the Vulcan continued to carry WE.177B in a tactical nuclear strike role as part of the British contribution to Europe's standing NATO forces, although they no longer held aircraft at 15 minutes readiness in peacetime. Two squadrons were also stationed in Cyprus as part of the Near East Air Force and assigned to CENTO in a strategic strike role. With the eventual

demise of the WE.177B and the Vulcan bombers, the Blackburn Buccaneer, SEPECAT Jaguar, and Panavia Tornado, continued with the WE.177C until its retirement in 1998. While not a like-for-like replacement, the multi-role Tornado strike bomber is the successor for the roles previously filled by the Vulcan.

Conventional Role

Although the aircraft's armament was primarily a nuclear weapon, in a conventional secondary role it was possible for the Vulcans to carry up to 21 1,000 lb (454 kg) bombs. Since the 1960s, the RAF's Vulcan squadrons had conducted routine training missions in practice for performing conventional bombing missions in addition to nuclear strike missions.

The only combat missions involving the Vulcan took place in 1982 during the Falklands War with Argentina. This was also the only time V-bombers took part in conventional warfare. The missions flown by the Vulcans became known as the “Black Buck” raids, which flew 3,889 mi (6,259 km) from Ascension Island to Stanley on the Falklands. On 1 May, the first mission was conducted by a single Vulcan that flew over Port Stanley and dropped its bombs on the airfield concentrating on the single runway, with one direct hit, making it unsuitable for fighter aircraft. The Vulcan's mission was quickly followed up by strikes against anti-air installations, flown by British Aerospace Sea Harriers from nearby Royal Navy carriers.

In total, three missions were flown against the airfield, two further missions to launch missiles at radar installations; another two missions were cancelled. Victor tankers conducted the air-to-air refueling; approximately 1.1 million gal (5 million L) of fuel were used in each mission. At the time, these missions held the record for the worlD's longest-distance raids. The Vulcan's ECM system was effective at jamming Argentine radars, British aircraft in the vicinity had a greatly reduced chance of coming under effective fire.

Five Vulcans were selected for the operation; their bomb bays were modified, the flight refueling system that had long been out of use was reinstated, the electronics updated, and new wing pylons fitted to carry an ECM pod and Shrike anti-radar missiles at wing hardpoint locations originally installed for carrying Skybolt missiles. The engineering work began on 9 April.

Maritime Radar Reconnaissance

In November 1973, No.27 Squadron reformed at RAF Scampton in the maritime radar reconnaissance role. Though initially equipped with a number of B.2 aircraft, the Squadron eventually operated nine B.2 (MRR) aircraft. The main external visual difference was the presence of a gloss paint finish, with a light grey undersurface, to protect against sea spray. TFR was not fitted and the aircraft were equipped with LORAN C navigational equipment. Five aircraft were further modified for the Squadron's secondary role of air sampling. These aircraft were distinguishable by the additional hardpoints outside of the underwing Skybolt points upon which could be hung pylons and the air-sampling pods, which had been constructed from de Havilland Sea Vixen drop tanks.

Aerial Refueling Role

After the end of the Falklands War in 1982, the Vulcan B.2 was due to be withdrawn from RAF service that year. However, the Falklands campaign had consumed much of the airframe fatigue life of the RAF's Victor tankers. While Vickers VC.10 tanker conversions had been ordered in 1979 and Lockheed TriStar tankers would be ordered subsequent to the conflict, as a stopgap measure six Vulcans were converted into single point tankers. The Vulcan tanker conversion was accomplished by removing the jammers from the ECM bay in the tail of the aircraft, and replacing them with a single Hose Drum Unit (HDU). An additional cylindrical bomb-bay tank was fitted, making a total of three, giving a fuel capacity of almost 100,000 lb (45,000 kg).

The go-ahead for converting the six aircraft was given on 4 May 1982. Just 50 days after being ordered, the first Vulcan tanker (XH561) was delivered to RAF Waddington. The Vulcan K.2s were operated by No.50 Squadron, along with three Vulcan B.2s, in support of UK air defense activities until it was disbanded in March 1984.

Engine Test Beds

The first prototype (VX770) had its Sapphire engines replaced with four 15,000 lbf (67 kN) Rolls-Royce Conway RCo.7 turbofans in 1957. It was transferred to Rolls-Royce as the Conway test bed. It flew with the Conways, the first turbofans in the world, until its fatal crash in September 1958.

The first Vulcan B.1 (XA889) was used for the flight clearances of the Olympus 102 and 104.

Vulcan B.1 (XA891) was fitted with four Olympus 200 engines in the spring of 1958 for intensive flying trials. The aircraft crashed in July 1958 during a routine test flight.

Vulcan B.1 (XA894) flew with five Olympus engines, the standard four Mk.101s, plus a reheated Olympus 320 destined for the BAC TSR-2 in an underslung nacelle. This aircraft was destroyed in a ground fire at Filton on 3 December 1962.

Vulcan B.1 (XA896) was withdrawn from RAF service in June 1964 and transferred to be converted to the test bed for the Bristol Siddeley BS100 vectored thrust turbofan for the Hawker Siddeley P.1154. The P.1154 was cancelled in February 1965 and XA896 was scrapped before being converted.

Vulcan B.1 (XA902) was withdrawn from RAF service after a landing accident in 1958. After rebuilding, it replaced VX770 as the Conway test bed, fitted with four RCo.11s. The two inner Conways were replaced with Rolls-Royce Speys, flying for the first time in this configuration on 12 October 1961.

Vulcan B.1 (XA903), surplus to Blue Steel trials, was converted to a similar layout to XA894 to flight test the Olympus 593 Concorde installation. The first flight was on 1 October 1966 and testing continued through to June 1971. In April 1973, XA903 flew with an underslung Rolls-Royce RB.199 turbofan destined for the Panavia Tornado. The RB.199 engine included both the reheat and thrust reverser functions. XA903 was the last B.1 to fly, being retired in February 1979.

Vulcan B.2 (XH557) was used by BSEL for developing the Olympus 301 and first flew with the larger engine in May 1961. It was returned to Woodford in 1964 to be refurbished for the RAF.

Variants [2]

- B.1: The initial production aircraft. First few with straight leading edge, later retrofitted with Phase 2 (kinked) wing. Early examples finished in silver, later changed to “anti-flash” white. Many converted to B.1A standard 1959-1963. Last few unmodified B.1s in RAF service with No. 230 OCU retired by 1966. Last flight by any B.1, an engine testbed (XA903), March 1979.
- B.1A: The B.1 with an Electronic Countermeasures (ECM) system in a new larger tail cone (as in B.2). Unlike the B.2, the B.1As did not undergo extensive wing strengthening for low-level flying and were withdrawn from service 1966-67.
- B.2: Developed version of the B.1. Larger, thinner wing than the B.1 (Phase 2C wing) and fitted with Olympus 201-202 engines of 17,000 lbf (76 kN) each, or Olympus 301 engines of 20,000 lbf (89 kN) each. Uprated electrics with Auxiliary Airborne Power Plant (AAPP) (Auxiliary power unit) and Ram Air Turbine (RAT). ECM similar to B.1A. Terrain-Following Radar (TFR) in nose thimble radome fitted to most aircraft in mid-60s. New Radar warning receiver aerials on tail fin giving it a square top from mid-1970s.
- B.2 (MRR): Nine B.2s converted to Maritime Radar Reconnaissance (MRR). TFR deleted. Five aircraft further modified for Air Sampling Role. Distinctive gloss finish with light grey underside.
- K.2: Six B.2s converted for air-to-air refueling with Mark 17 Hose Drum Unit (HDU) mounted semi-recessed in tail cone. TFR deleted. Fitted with three bomb-bay drum tanks, it was the only mark of Vulcan that could jettison fuel in an emergency.
- B.3: Proposed version intended as a long endurance missile carrier capable of carrying up to six Skybolt ALBMs on flights of up to 12 hours duration. Never built.

Production [2]

A total of 134 production Vulcans were assembled at Woodford Aerodrome, 45 to the B.1 design and 89 were B.2 models, the last being delivered to the RAF in January 1965.

Avro 698 Vulcan Production Details

Contract Date	Quantity	Variant	Notes
6 July 1948	2	Prototypes	Two prototypes delivered in August 1952 and September 1953
14 August 1952	25	Vulcan B.1	First flight of production aircraft 4 February 1955, delivered between June 1955 and December 1957.
30 September 1954	20	Vulcan B.1	delivered between January 1958 and April 1959.
30 September 1954	17	Vulcan B.2	Delivered between September 1959 and December 1960
31 March 1955	8	Vulcan B.2	Delivered between January and May 1961
25 February 1956	24	Vulcan B.2	Delivered between July 1961 and November 1962
22 January 1958	40	Vulcan B.2	Delivered between 2/1963 and 1/1965, one aircraft not flown and used as a static test airframe
Total	136		

Operators [2]

United Kingdom

- Aeroplane and Armament Experimental Establishment aircraft used for trials and evaluation
- Royal Air Force:
  - No. 9 Squadron RAF (Operated the B.2 from 1962 to 1982)
  - No. 12 Squadron RAF (Operated the B.2 from 1962 to 1967)
  - No. 27 Squadron RAF (Operated the B.2 from 1961 to 1972 and the B.2 (MRR) from 1973 to 1982)
  - No. 35 Squadron RAF (Operated the B.2 from 1962 to 1982)
  - No. 44 Squadron RAF (Operated the B.1/B.1A from 1960 to 1967 and the B.2 from 1966 to 1982)
  - No. 50 Squadron RAF (Operated the B.1/B.1A from 1961 to 1966, the B.2 from 1966 to 1984 and the K.2 from 1982 to 1984)
  - No. 83 Squadron RAF (the first Vulcan squadron operated the B.1/B.1A from 1957 to 1960 and the B.2 from 1960 to 1969)
  - No. 101 Squadron RAF (Operated the B.1/B1A from 1957 to 1967 and the B.2 from 1967 to 1982)
  - No. 617 Squadron RAF (Operated the B.1/B1A from 1958 to 1961 and the B.2 from 1961 to 1981)
  - No. 230 Operational Conversion Unit RAF[198] from 1956 to 1981. The first unit to operate the Vulcan, it provided conversion to type and operational training for Vulcan aircrew.
  - Bomber Command Development Unit
- Vulcan To The Sky Trust (flying XH558 currently based at Robin Hood Airport Doncaster Sheffield)
- Aircraft were also operated at various times under the direction of the Ministry of Supply/Aviation for trials and evaluation by Avro, Bristol Siddeley Engines, Rolls-Royce and the Blind Landing Experimental Unit (BLEU).

Avro Vulcan B.2 (XH558) [2]

The last airworthy Vulcan (XH558) has been restored to flying condition by the “Vulcan to the Sky Trust” after years of effort and fundraising. The first post-restoration flight, which lasted 34 minutes, took place on 18 October 2007.

The aircraft's airworthiness status was in peril as maintenance funding was in need before the end of February 2010. At the last moment an anonymous benefactor presented £458,000 to the foundation, ensuring its airworthiness for both its 50th birthday and the prospect of a flight performance for the 2012 Summer Olympic Games opening ceremony in London. It is currently based at Doncaster Robin Hood Airport, formerly RAF Finningley.

Specifications (Avro 698 Vulcan B.Mk.1 and B.Mk.2) [2,3]

Type

- Strategic four-jet engine heavy long-range bomber [2]

Accommodation [2]

- Crew: 5 (pilot, co-pilot, AEO, Navigator Radar, Navigator Plotter)

Manufacturers: [3]

- A.V. Roe and Co Ltd, Greengate, Middleton, Manchester; and Woodford Aerodrome, Cheshire; restyled the Avro-Whitworth Division of Hawker Siddeley Aviation, July 8, 1963

Powerplants (First prototype): [3]

- 4 × 6,500 lb st Rolls-Royce Avon R.A.3
- 4 × 8,000 lb st Armstrong Siddeley Sapphire
- 4 × 15,000 lb st Rolls-Royce Conway R.Co.7

Powerplants (Second prototype): [3]

- 4 × 9,750 Bristol Olympus 100

Powerplants (Vulcan B.Mk.1): [3]

- 4 × 11,000 lb st Bristol Olympus 101
- 4 × 12,000 lb st Bristol Olympus 102
- 4 × 13,500 lb st Bristol Olympus 104
- 4 × 17,250 lb st Roles-Royce Conway R.Co.11 (XA902 only)
- 4 × 16,000 lb st Bristol Olympus 200 (XA891 only)

Powerplants (Vulcan B.Mk.2): [3]

- 4 × 16,000 lb st Bristol Olympus 200 (XH533 only)
- 4 × 17,000 lb st Bristol Olympus 201
- 4 × 20,000 lb st Bristol Olympus 301

Dimensions, Weights and Performances (Vulcan B.Mk.1) [3]

- Span: 99 ft 0 in
- Length: 97 ft 1 in
- Height: 26 ft 6 in
- Wing area: 3,554 ft^2
- All-up weight: 170,000 lb

- Maximum speed: 625 mph
- Cruising speed: 607 mph
- Service Ceiling: 55,000 ft
- Range: 3,000 miles

Dimensions, Weights and Performances (Vulcan B.Mk.2) [3]

- Span: 111 ft 0 in
- Length: 99 ft 11 in
- Height: 27 ft 2 in
- Wing area: 3,964 ft^2
- All-up weight: 200,000 lb
- Maximum speed: 645 mph
- Cruising speed: 620 mph
- Service Ceiling: 60,000 ft
- Range: 4,600 miles

Armament [2]

- 21 × 1,000 pounds (454 kg) of conventional bombs
- 1 × Blue Danube nuclear gravity bomb
- 1 × Violet Club 400 kT nuclear gravity bomb
- 1 × U.S. Mark 5 nuclear gravity bomb supplied under Project E
- 1 × Yellow Sun Mk.1 400 kT nuclear gravity bomb
- 1 × Yellow Sun Mk 2 1.1 MT thermonuclear gravity bomb
- 1 × Red Beard nuclear gravity bomb

Comparison of Variants [2]

Comparison of Avro 698 Vulcan Variants					
	Vulcan B.1	**Vulcan B.1A**	**Vulcan B.2**	**Vulcan B.2(MRR)**	**Vulcan K.2**
Wingspan:	99 ft 5 in	99 ft 5 in	111 ft 0 in	111 ft 0 in	111 ft 0 in
Length:	97 ft 1 in	105 ft 6 in (99 ft 11 in without probe)			
Height:	26 ft 6 in	26 ft 6 in	27 ft 1 in	27 ft 1 in	27 ft 1 in
Wing area:	3,554 ft^2	3,554 ft^2	3,964 ft^2	3,964 ft^2	3,964 ft^2
Maximum take-off weight:	167,000 lb 185,000 lb** (operational necessity)	167,000 lb 185,000 lb** (operational necessity)	204,000 lb	204,000 lb	204,000 lb
Cruising speed:	Mach 0.86 indicated	Mach 0.86 indicated	Mach 0.86 indicated	Mach 0.86 indicated	Mach 0.86 indicated
Maximum speed:	Mach 0.95	Mach 0.95	Mach 0.93 indicated	Mach 0.93	unknown

	indicated	indicated	(Mach 0.92 with 301 engines)	indicated	
Service ceiling:	55,000 ft	55,000 ft	45,000 ft to 56,000 ft	45,000 ft to 56,000 ft	45,000 ft to 56,000 ft
Electrical system:	112V DC	112V DC	200V AC 3-phase 400 Hz	200V AC 3-phase 400 Hz	200V AC 3-phase 400 Hz
Emergency electrical system:	Battery	Battery	Ram air turbine and Airborne Auxiliary Power Plane	Ram air turbine and Airborne Auxiliary Power Plane	Ram air turbine and Airborne Auxiliary Power Plane
Powerplants:	4 × Bristol Olympus 101, 102 or 104	4 × Bristol Olympus 104	4 × Bristol Siddeley Olympus 200-series, 301	4 × Bristol Siddeley Olympus 200-series	4 × Bristol Siddeley Olympus 200-series
Fuel capacity (main):	9,280 gal avtur	9,280 gal avtur	9,260 gal avtur	9,260 gal avtur	9,260 gal avtur
Fuel capacity (bomb bay)	none		0-1,990 gal avtur	1,990 gal avtur	2,985 gal avtur
Powered flying controls:	1 × rudder (duplex), 4 × elevators, 4 × ailerons		1 × rudder (duplex), 8 × elevons		
Armament:	1 × free-fall nuclear bomb “or” 21 × 1,000 lb conventional bombs		1 × Blue Steel missile “or” 1 × free-fall nuclear bomb “or” 21 × 1,000 lb conventional bombs	none	

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